

Profiling the SO₂ Plume from Volcan Turrialba: Ticosonde Balloon Measurements Compared with OMI and OMPS Retrievals

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MOTIVATION and APPROACH

Unlike many other atmospheric trace species, the large-scale distribution of SO₂ is affected by episodic, spatially inhomogeneous and occasionally large-magnitude emissions events. Both of these represent a challenge for remote sensing of SO₂ from space, and it is thus important to take advantage of every opportunity to obtain ground truth measurements of SO₂.

We have been using indirect and more recently a direct dual ozone sonde techniques to estimate volcanic SO₂ over San José, Costa Rica. We compare these two *in situ* approaches and then compare these to SO₂ column observations obtained from two satellite instruments: the Ozone Monitoring Instrument (OMI) on Aura and the Ozone Mapping and Profiler Suite (OMPS) on Suomi-NPP.



Photo: Simon Carn



Photo: Smithsonian Global Volcanism Program

Two recent views of Turrialba

A UNIQUE VALIDATION OPPORTUNITY

Turrialba [10.0°N, 83.8°W, elev. 3440 m] is a large stratovolcano located ~35 km east of the San José, Costa Rica. Activity re-commenced in 1996 and has led up to a series of five eruptions, four of them explosive, in the last five years. These have occurred during an **extended period of fumarolic activity and emission of SO₂**.

The NASA Ticosonde program began making **ozone sonde measurements** in the San José metropolitan area in 2005. The following year, we began to see notches in the ozone profiles that were consistent with interference from SO₂ in the ECC ozone sonde. We determined that **the most likely source of the SO₂ was fumarolic emissions from the summit craters of Turrialba**.

In February 2012 we showed **that a dual-ozone sonde technique could successfully detect the Turrialba plume** at San Jose. In July 2013, we began flying dual ozonesondes on a regular basis, and we now have a data base of 24 dual sonde launches along with over 80 regular ozone sondes with notched profiles in the lower troposphere.

DUAL-SONDE DIFFERENCE METHOD vs. NOTCH INFERENCE METHOD

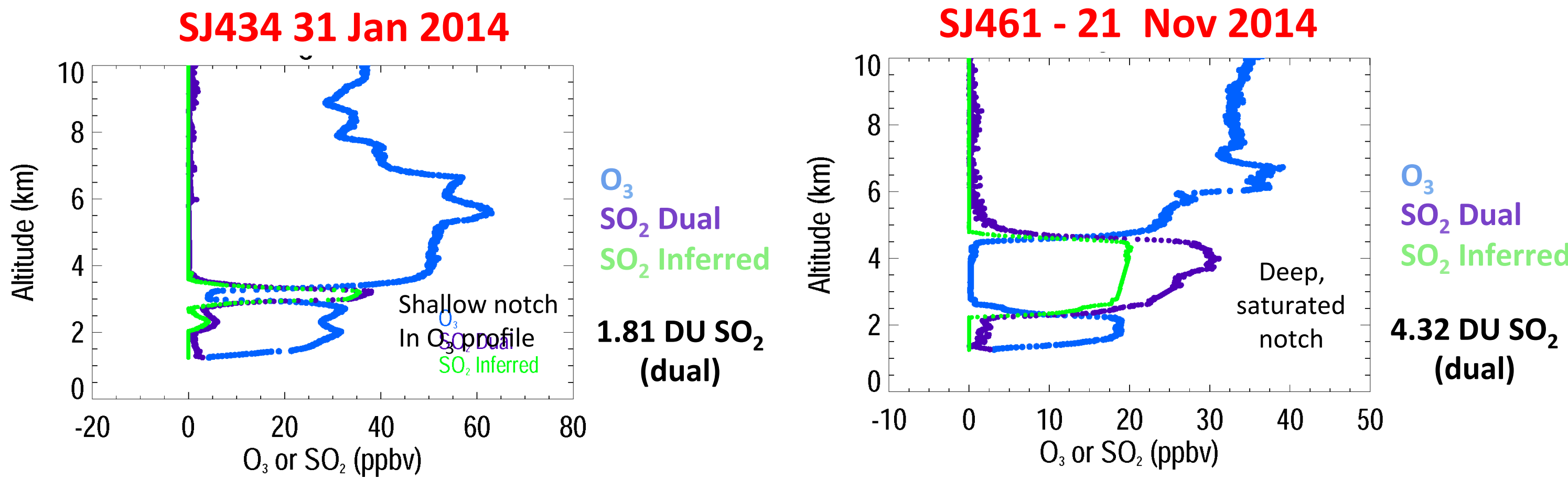


Figure 1: For dual sonde flights, we compare the SO₂ derived using the technique of Morris *et al.* [2010] (dual sonde, filtered minus unfiltered ozone measurements, VIOLET) with that a notch-inferred (GREEN) value estimated from the unfiltered ozone profile only. The case on the left shows a very good result for the inferred vs. “direct” measurement, while the case on the right shows the limitation of the inferred approach in plumes with very high SO₂ concentrations.

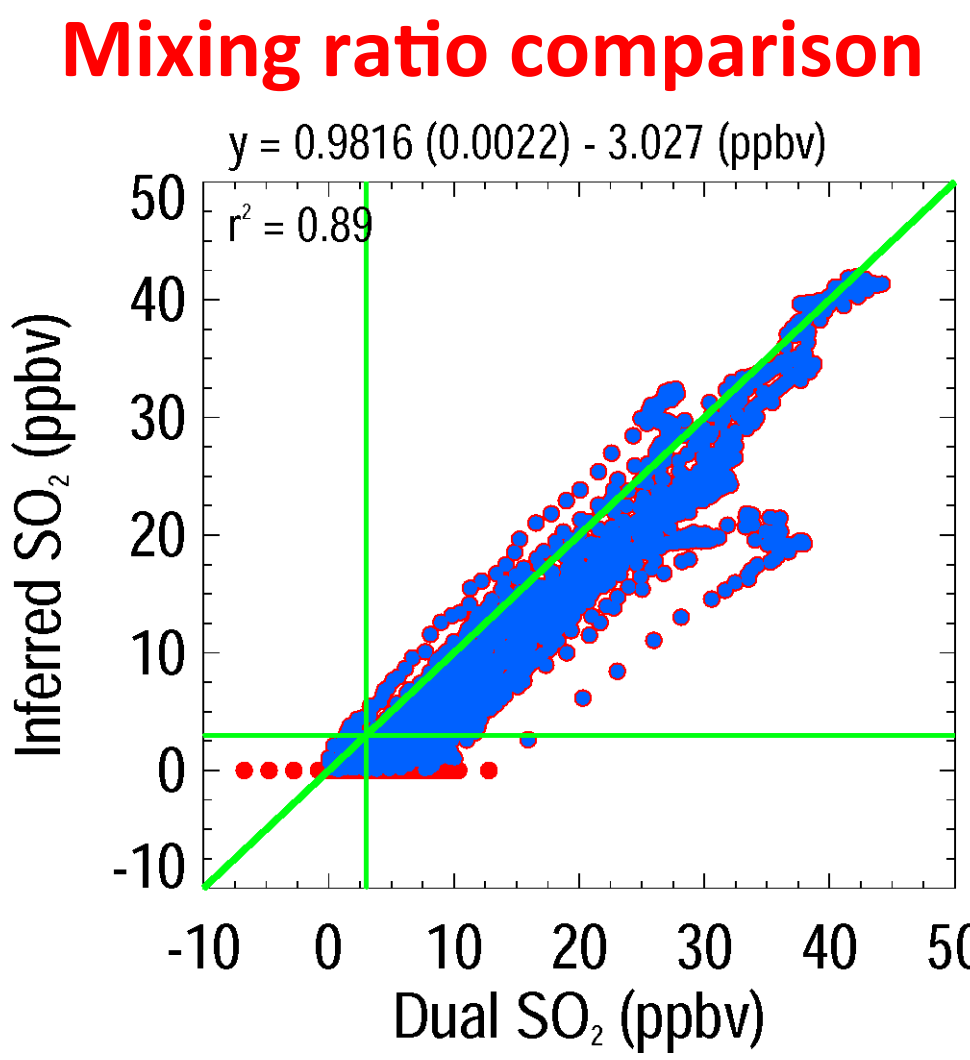


Figure 2: Comparison of 100-m resolution SO₂ mixing ratios derived from direct method (abscissa) and notch-inference method for our set of 24 dual sondes. Red are all points, while blue are comparisons only where the inferred approach identifies a notch.

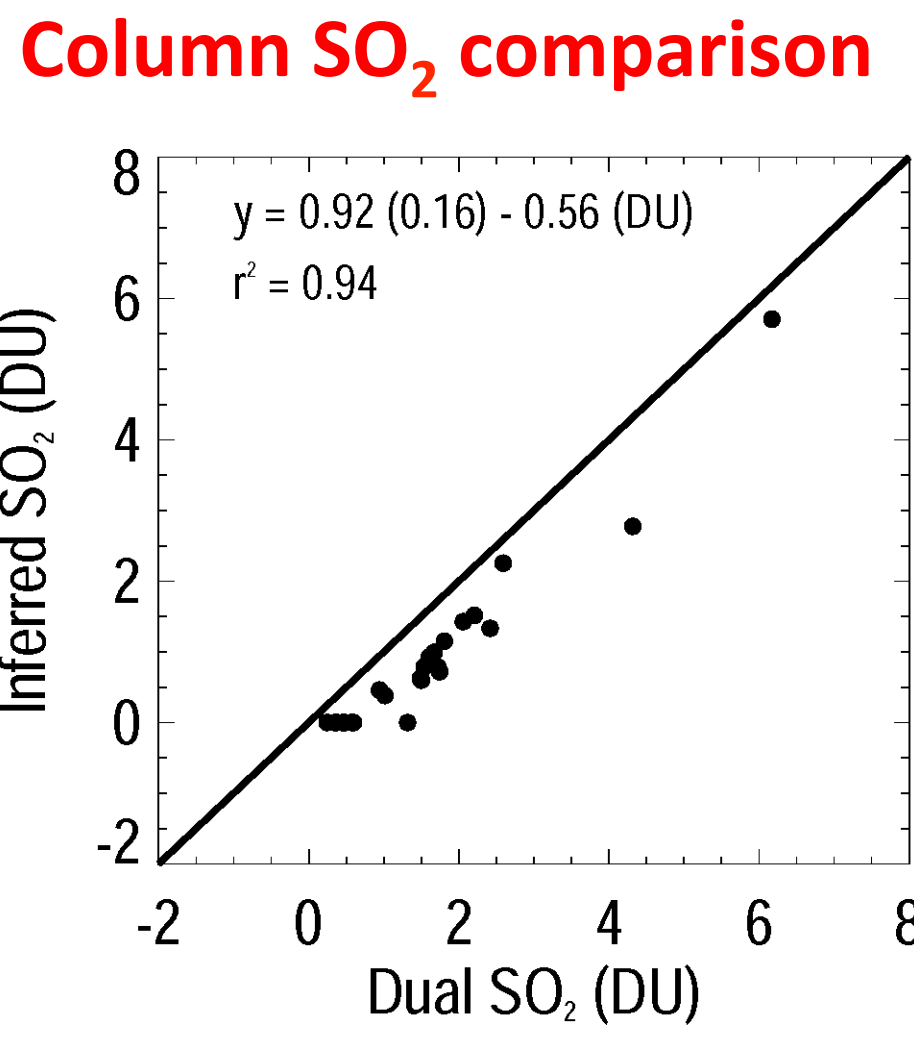


Figure 3: As in Fig. 2, but for tropospheric column SO₂.

Figs. 2 and 3 show that the **inferred SO₂ profile concentrations and column estimates are very useful but represent lower limits** due to the ozonesonde instrument design (which does not permit negative values) and in layers, as seen in Figure 1 at right, in which both an O₃ and an SO₂ feature exist.

SUMMARY AND FUTURE WORK

With over two dozen dual sonde launches to date and a growing record regular ozone sondes showing evidence of volcanic SO₂ plumes, we have assembled a unique data set to validate both past and forthcoming retrievals of column SO₂ from both OMI and OMPS as well as future instruments such as TROPOMI. This initial effort demonstrates the advantages and the challenges inherent in validating satellite measurements of small-scale and intrinsically dynamic feature in the atmosphere. Further progress will require consideration of plume trajectories as well as a better understanding of the near-field evolution of the plume.

COMPARISONS TO OMI LF RETRIEVALS: NOTCH-INFERENCE MEASUREMENTS, 2006-present

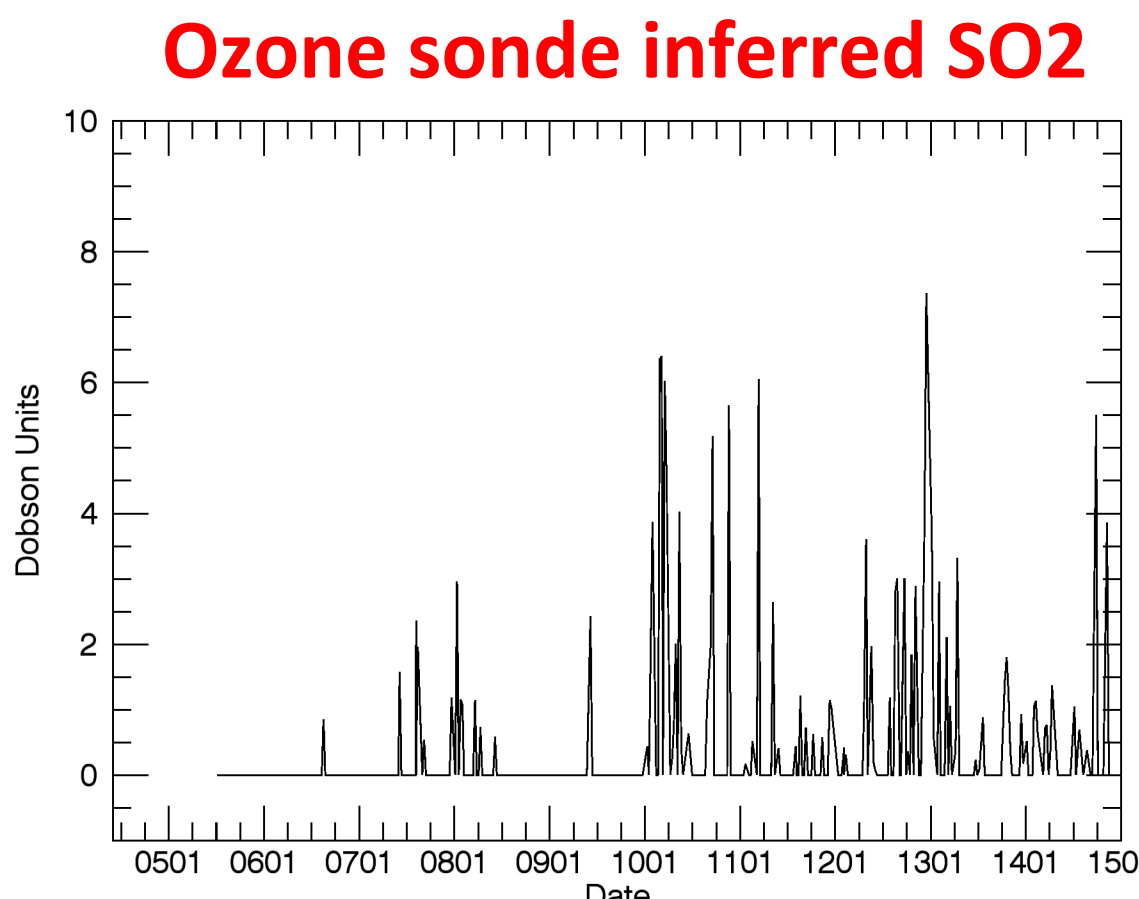


Figure 4: Balloon sonde SO₂ columns inferred from notches in O₃ profiles.

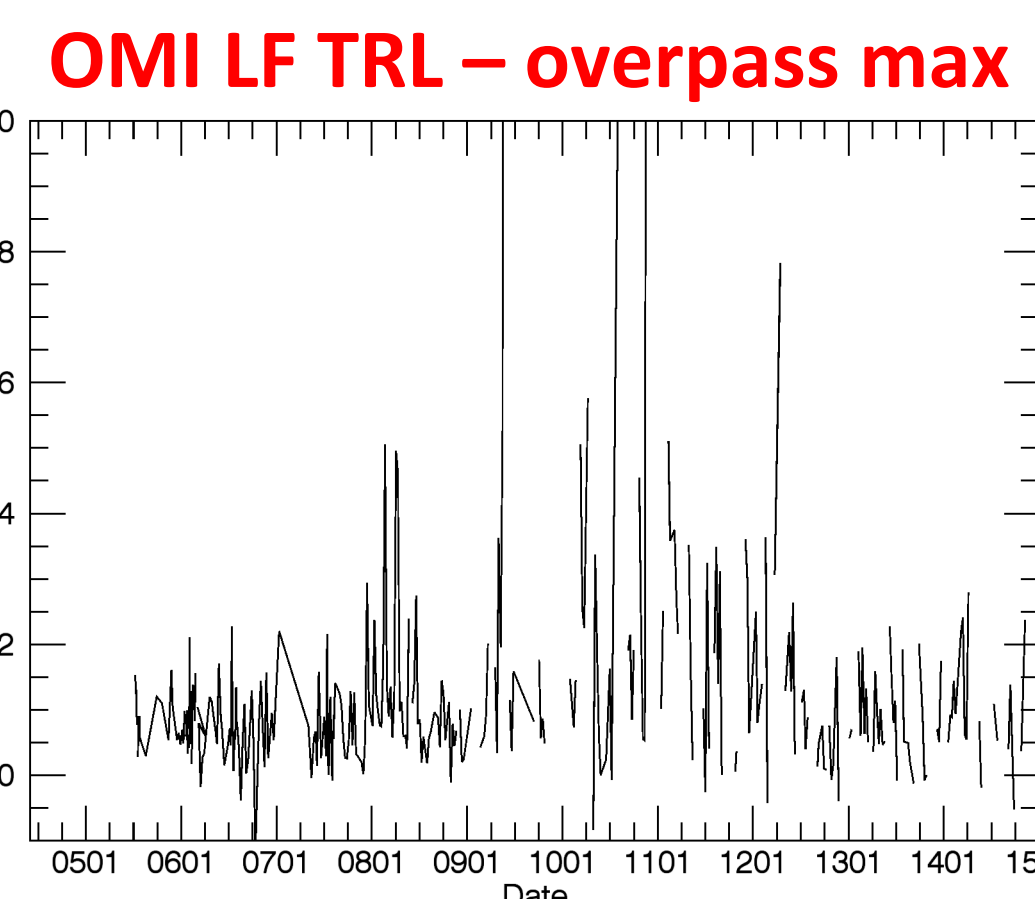


Figure 5: Overpass maximum of OMI TRL (lower troposphere) linear-fit (LF) product, sonde dates.

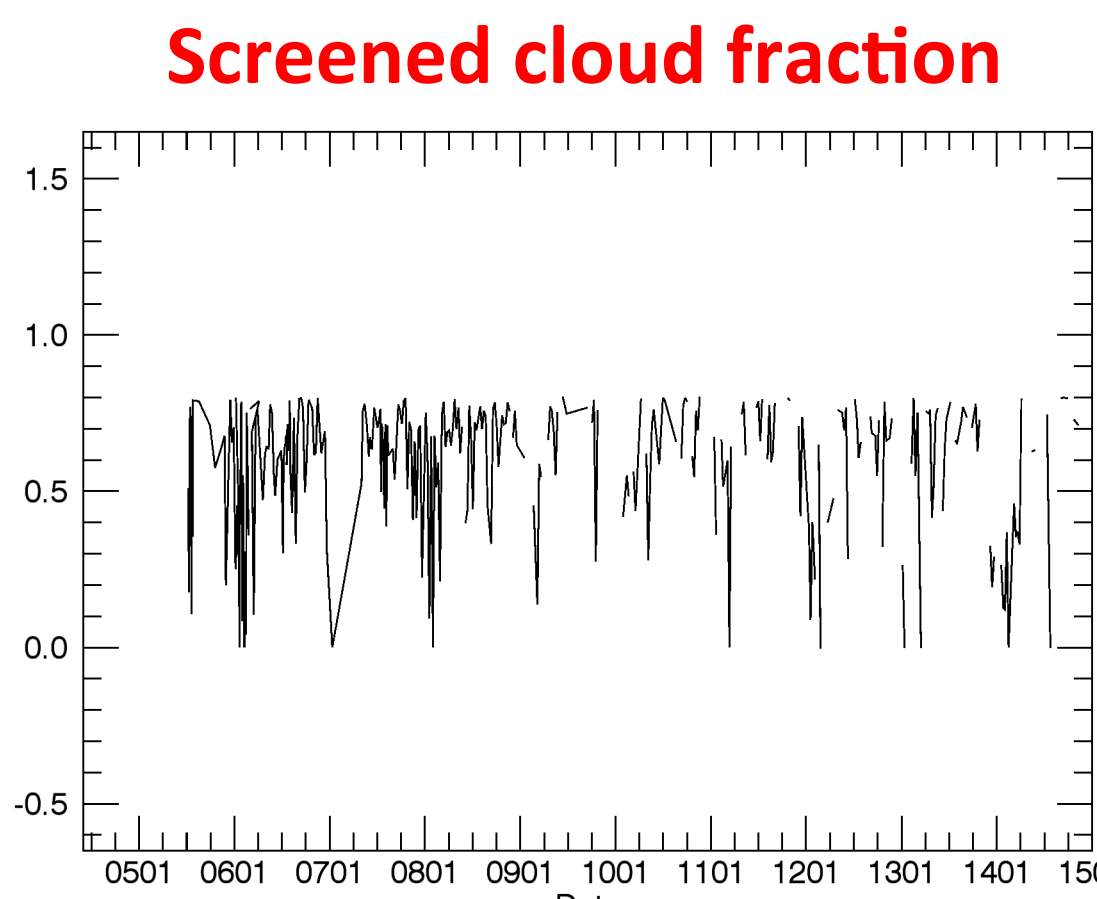


Figure 6: Retrievals with CLD_F > 0.8 screened out.

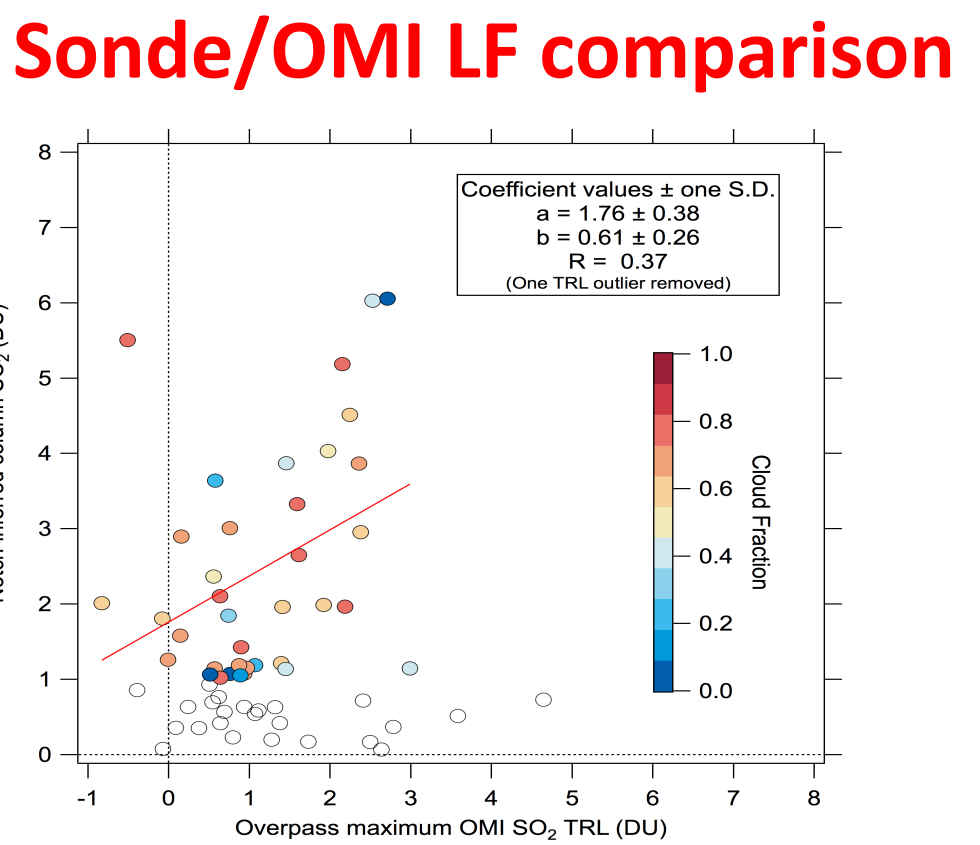


Figure 7: Inferred SO₂ column (>1 DU) vs overpass max TRL

Figs. 4 and 5 demonstrate that the OMI LF product is capturing the major episodes of SO₂ “notching” in the sondes since 2006. After screening out high cloud fraction retrievals (Fig.6) – but not for plume trajectory – **we find a positive relationship between the in situ and remote sensing measurements, with the retrieval dynamic range ~60% of the range of the sondes.**

SAMPLE COMPARISONS TO OMI LF and OMPS PCA SATELLITE RETRIEVALS: DUAL SONDE MEASUREMENTS since 2013

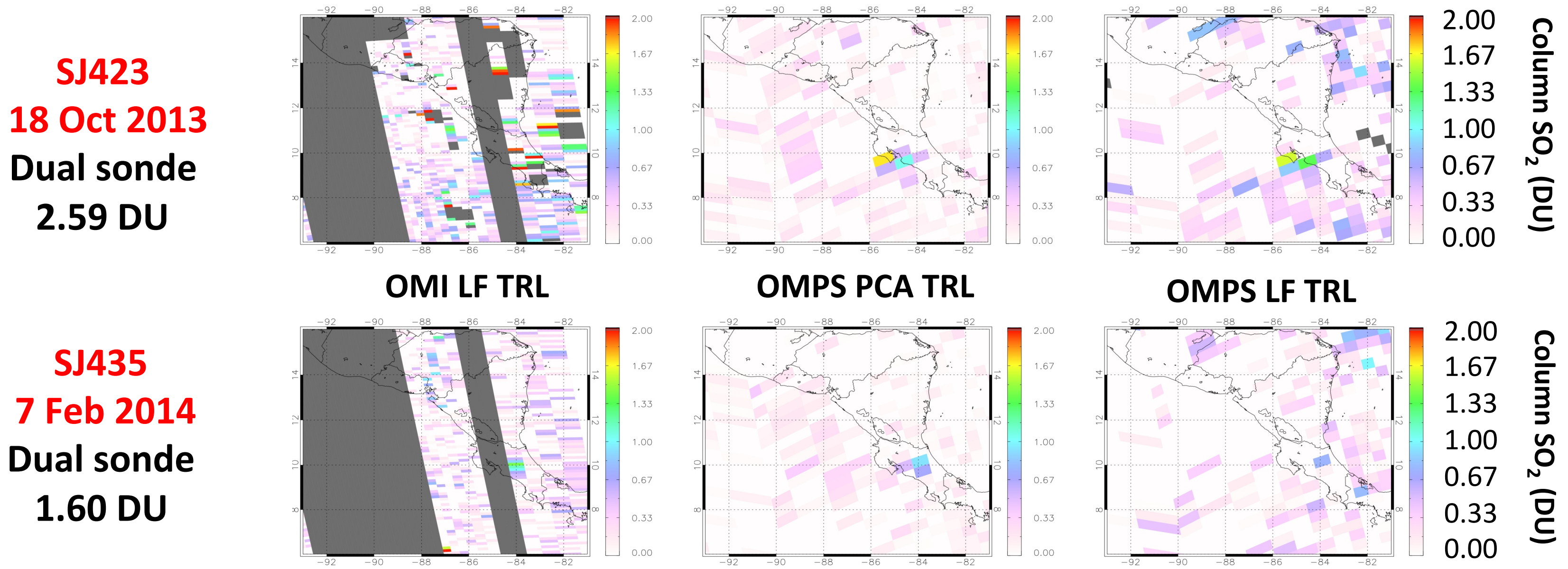


Figure 8: Columns of lower tropospheric SO₂ from OMI LF, OMPS PCA and LF TRL on two days with dual sondes.

Shown in the a above figure are maps for two dual sonde launch days of the OMI standard LF product along with the OMPS LF and the OMPS Principal Components Analysis (PCA) retrievals. **The PCA retrieval shows a lower noise level than its counterpart.** However, because of **the higher resolution of OMI, the standard product permits a closer match to the sonde measurements than OMPS** at sites such as San Jose where the plume may not have undergone substantial spreading.